シンガポールの都市化が同地域の対流性降水に及ぼす影響

Impact of urbanization on convective rainfall in Singapore

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There is still no consensus on the urban impact on convective precipitation over large cities, especially in the tropics. Here we investigate the urban-associated precipitation over Singapore, focusing on the urban modification in its diurnal cycle. We use supper high-resolution numerical weather prediction (NWP) system, developed at the Meteorological Service Singapore, to simulate the rainfall climate over the region during the five November between 2010 and 2014. November is the inter-monsoon month in Singapore, characterized by weak prevalent wind speed, providing favorable conditions for localized convections. Reanalysis data ERA5 is used as initial and boundary conditions for the simulations. Urban-land-surface data, used as the input for the model, are estimated from remote sensing data. Also, anthropogenic heat release data are estimated from inventory and incorporated into the NWP model. The simulated results are verified against ground-based observations, and the NWP shows high performance on the rainfall climate, primarily reproduces well the diurnal variation, the timing and magnitude of the peak rainfall in late afternoons.

A sensitivity simulation in which the urban-land surface has been replaced to vegetation is conducted and compared to the simulation with the urban-land surface to isolate the possible urban effect on the rainfall climate. Results reveal that urbanization is likely to significantly modified the local rainfall climate, responsible for creating a rainfall "hot spot" over Singapore and Johor Bahru, an urban area in the southern tip of the Malay Peninsula. The urbanization is found to add 20–30 % on the peak rainfall in late afternoons and evenings. This contribution is a relatively high referred to the mid-latitude cities, where urbanization is responsible for rainfall addition of 10 – 20 %. We suggest that the durable localized nature of rainfall in the tropics is a reason for this high urban impact; meanwhile, in mid-latitudes, rainfall is preferably driven by meso- and synoptic-scale phenomena. The high urbanization impact on rainfall found in this study is consistent to previous reports for other tropical cities, e.g., Jakarta or Kuala Lumpur or subtropical cities, e.g., in Pearl River Delta (South China).

Simulation results are analyzed to explain the physical mechanisms responsible for increase in urban precipitation. We found the robust enhancement of convections over the urban area in senses of that the urbanization strengthens vertical wind velocity and increases upper-air water vapor and ice amounts. The increase in the urban heat island effect over Singapore works to destabilize the urban boundary layer and then induce low-level wind convergence. Although the urban devegetation reduces near-surface evapotranspiration, the surplus of upper-air water moisture is likely a consequence of the advection as sea breeze enhanced due to land-sea temperature contrast. Also, the modification of sea-breeze front seaward explains the increase of convection chance over the urban area.